D E C L A R A T I O N

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FUEL INJECTOR

Description

Background Information

The present invention is based on a fuel injector according to the definition of the species in the main claim.

During engine-driven operation, the problem generally occurs in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, particularly in the case of direct gasoline injection or the injection of diesel fuel, that the downstream tip of the fuel injector projecting into the combustion chamber is coked by fuel deposits or that soot particles formed in the flame front are deposited on the valve tip. Therefore, in the case of fuel injectors projecting into the combustion chamber known heretofore, there is the danger during their lifetime of a negative influence on the spray parameters (e.g., static flow quantity, spray dispersal angle, droplet size, skeining) that can lead to operational disturbances of the internal combustion engine or even to a malfunction of the injection valve.

Advantages of the Invention

The fuel injector of the present invention having the characterizing features of the main claim has the advantage that these previously mentioned negative effects of coking (soot depositing) on the valve tip projecting into the combustion chamber are restricted or eliminated. Due to the application of coatings according to the present invention on the downstream valve end, especially around the mouth regions of the outlets, the coking or deposit formation (soot) on the

valve end which generally have a negative effect on the spray parameters and the valve parameters are reduced or prevented.

Advantageous refinements of and improvements to the fuel injector characterized in the main claim are possible through the measures characterized in the subordinate claims.

It is advantageous to apply layers on the valve end, by which either a catalytic conversion (combustion) of the deposits takes place or by which the surface energy and/or the surface roughness of the component to be coated are/is reduced, so that a change in the wetting behavior is achieved or the formation of a reaction layer is prevented.

Brief Description of the Drawing

An exemplary embodiment of the present invention is represented in simplified form in the drawing and elucidated in greater detail in the description that follows. The figures show:

Figure 1 a fuel injector inserted in a receiving bore of a cylinder head;

Figure 2 a fuel injector in a longitudinal section;

Figure 3 a first exemplary embodiment of a valve end coated according to the present invention;

Figure 4 a second exemplary embodiment of a valve end coated according to the present invention;

Figure 5 an alternative guide and seat region at the spray-discharge-side valve end;

Figure 6 a longitudinal section of a fuel injector for self-igniting internal combustion engines; and

Figure 7 the end of the fuel injector according to Fig. 6 on

the side of the combustion chamber.

Description of the Exemplary Embodiment

Fig. 1 shows a sectional view of a cylinder head 1 of an internal combustion engine, in particular a mixture-compressing internal combustion engine having externally supplied ignition. A stepped receiving bore 2 is formed in cylinder head 1, which extends symmetrically along a longitudinal axis 4 up to a combustion chamber 3. A fuel injector 5 according to the present invention is inserted in receiving bore 2 of cylinder head 1. Fuel injector 5 is used for the direct injection of fuel, especially gasoline, but also diesel, for example, as shown by Fig. 6 and 7, into combustion chamber 3 of the internal combustion engine. Fuel injector 5 is preferably actuable electromagnetically, via an electrical connection cable 6. The fuel is supplied to fuel injector 5 via an intake nipple 7. Fuel injector 5 shown in Fig. 1 is what is known as a top-feed fuel injector, in which the fuel is guided from intake nipple 7 in the axial direction through the entire fuel injector 5, and is spray-discharged into combustion chamber 3 at spray-discharge-side end 8 lying across from the intake-side end.

To protect fuel injector 5 from overheating in the proximity of combustion chamber 3, fuel injector 5 is at least partially surrounded by, for example, a thermal protection sleeve 9 also introduced in receiving bore 2, for example, although such a sleeve may also be omitted.

Fig. 2 shows an exemplary embodiment of a fuel injector 5 according to the present invention in a sectional view. It is an electromagnetically actuable valve, which has a tubular, largely hollow-cylindrical core 11, which is at least partially surrounded by a solenoid coil 10 and serves as inner pole of a magnetic circuit. A, for example, stepped coil shell

13 made of plastic accommodates a winding of solenoid coil 10 and, together with core 11 and a non-magnetic intermediate part 14 partially surrounded by solenoid coil 1, allows an especially compact and short design of the fuel injector in the region of solenoid coil 1. Instead of the electromagnetic actuating element, fuel injector 5 may also be actuated piezoelectrically or magnetorestrictively.

Provided in core 11 is a straight-through longitudinal opening 15, which extends along a longitudinal valve axis that coincides with longitudinal axis 4 of receiving bore 2. Core 11 of the magnetic circuit is also used as intake nipple 7. Fixedly connected to core 11 above magnetic coil 1 is an external metal (e.g. ferritic) housing part 16, which closes the magnetic circuit as an external pole or an external conductive element and completely surrounds magnetic coil 1 at least in the circumferential direction. Provided on the incoming side in longitudinal opening 15 of core 11 is a fuel filter 17, which is responsible for filtering out such fuel components that could cause blockage of or damage to the fuel injector due to their size.

A lower tubular housing part 18 is tightly and permanently joined to upper housing part 16 and, for example, encloses or accommodates an axially movable valve component having an armature 19, a rod-shaped valve needle 20, and an elongated valve seat support 21. Both housing parts 16 and 18 are permanently joined together by a circumferential weld, for example. The sealing between housing part 18 and valve seat support 21 is implemented with the aid of a sealing ring 22, for instance. Valve seat support 21 has an inner feed-through opening 24 across its entire axial extension, which runs concentrically with the longitudinal valve axis.

Via its lower end, which simultaneously also represents the

downstream end of entire fuel injector 5, valve seat support 21 surrounds a disk-shaped valve seat element 26, which is fitted in feed-through opening 24 and has a valve seat surface 27 which tapers frustoconically in a downstream direction. Valve needle 20, which has a valve-closure section 28 at its downstream end, is disposed in feed-through opening 24. As is known, this, for example, spherical, part-spherical or spherically tapering valve-closure section 28 cooperates with a valve seat surface 27 provided in valve seat element 26. At least one outlet 32 for the fuel is introduced in valve seat element 26 downstream from valve seat surface 27.

To guide valve needle 20 during its axial movement with armature 19 along the longitudinal valve axis, there is, for one, a guide opening 34 provided in valve-seat support 21 at the end facing armature 19 and, for another, a disk-shaped guide element 35, which is situated upstream from valve-seat element 26 and includes a dimensionally accurate guide opening 36.

The lift of valve needle 20 is determined by the installed state of valve-seat element 26. When magnetic coil 1 is not energized, one end position of valve needle 20 is defined by valve-closure section 28 resting against valve-seat surface 27 of valve-seat element 26, whereas when magnetic coil 1 is energized, the other end position of valve needle 20 is defined by armature 19 resting against the downstream end face of core 11. The surfaces of the components in the latter stop region are chromium-plated, for example.

The electrical contacting of solenoid coil 1 and therefore its excitation is implemented via contact elements 43, which are provided with a plastic extrusion coat 44 on the outside of coil shell 13. Plastic extrusion coat 44 may also extend to additional components (housing parts 16 and 18, for example)

of fuel injector 5. Electrical connection cable 6 via which solenoid coil 1 is energized extends out of plastic extrusion coat 44.

The guide and seat region provided in the spray-discharge-side end of valve seat support 21 in its feed-through openings 24 is formed by three axially sequential, disk-shaped elements separated in their function. Following one another in the downstream direction are guide element 35, a swirl element 47, and valve seat element 26. A compression spring 50 enveloping valve needle 20 stresses the three elements 35, 47, and 26 in valve seat support 21. Swirl element 47 may be produced cost-effectively for instance by stamping, wire eroding, laser cutting, etching or other known methods, from sheet metal or by galvanic deposition. An inner swirl chamber and a multitude of swirl channels discharging into the swirl chamber are provided inside swirl element 47. In this manner the fuel to be spray-discharged is provided with a swirl component in front of valve seat 27, so that the flow enters outlet 32 with a swirl, and a spray having fine turbulence and excellent atomization is delivered into combustion chamber 3.

In motor-driven operation, when fuel is directly injected into the combustion chamber of an internal combustion chamber, the problem generally arises that the downstream tip of the fuel injector projecting into the combustion chamber is coked by fuel deposits or that soot particles formed in the flame front are deposited on the valve tip. Therefore, in the case of injection valves projecting into the combustion chamber known heretofore, there is the danger during their lifetime of a negative influence on the spray parameters (e.g., static flow quantity, spray dispersal angle, droplet size, skeining) that can lead to operational disturbances of the internal combustion engine or even to a malfunction of the injection valve.

According to the present invention, the aforementioned problems are limited or eliminated by the application of coatings on valve end 8. The use of different coatings achieves different effects on surface 54 of the component to be coated, e.g., at valve seat element 26 made of Cr steel; however, all measures ultimately have as their goal to reduce or prevent the coking or deposit formation (soot) on valve end 8 that have a generally negative effect on the spray parameters and the valve function. In the following text, individual coating options are described in greater detail.

The catalytically acting coatings represent a first group of coatings. The electrolytically applied layers ensure a catalytic conversion (combustion) of the deposited soot particles, or they prevent the deposition of carbon particles in the first place. Suitable materials for such a coating to avoid coking are cobalt and nickel oxides and oxides of alloys of the mentioned metals. The noble metals Ru, Rh, Pd, Os, Ir, and Pt or alloys of these metals, among themselves or together with other metals, likewise exhibit catalytic effectiveness. The desired layers are produced by, e.g., electrochemical metal deposition or metal deposition without an external current. In the case of Ni, Co or their alloys, it is also possible to utilize the oxide formation in air or an additional oxide step (wet-chemical, plasma).

Coatings by which the wetting behavior at the corresponding surface 54 is modified form a second large group. Because of the coatings, the surface energy and/or the surface roughness of the critical regions on valve end 8 are reduced. This increases the boundary-surface energy between surface 54 and the fuel, which worsens the wetting. In this way the fuel droplets are able to roll off the regions coated according to the present invention and be carried away by the surrounding flow at valve end 8. Permanent wetting of valve end 8 no

longer takes place. Ceramic layers, carbon layers, which may or may not contain metal, or fluorine-containing layers lend themselves for such layers. The fluorine-containing layers are, for example, thermo-resistant PTFE-like layers or, in particular, organic ceramic layers or what is known as Ormocer® layers of fluorosilicate (FAS). Such fluorine-containing layers are applied by spraying or dipping, for example. Sapphire layers are conceivable as well.

Coatings by which a reactive layer may be prevented form a third group. Among these are, e.g., nitride layers (TiN, CrN) or oxide layers (tantalum oxide, titanium oxide). In these layers, particles that have evaporated in a vacuum furnace deposit on surfaces 54 to be coated, similar to sputtering.

The regions to be coated on valve end 8 are in particular those that directly surround the at least one outlet 32 in its mouth region 55. Namely, a deposit of soot particles in outlet 32 and/or at its immediate boundary edge leads in particular to the disadvantageous influencing of the spray parameters (e.g. static flow quantity, spray dispersal angle, droplet size, skeining) indicated above. Thus, in any case, a coating should be applied at the downstream end (mouth region 55) of each individual outlet 32, regardless of on which component of fuel injector 5 outlet openings 32 are formed.

Fig. 3 and 4 show two exemplary embodiments of valve ends 8, coated according to the present invention, in bottom views which differ in that, in one case, entire downstream component surface 54 of the component having outlet 32, here valve seat element 26, is coated (Figure 3), and in the other case, only an annular partial area of downstream component surface 54 is coated around the at least one outlet 32 (Figure 4). The dotted areas are intended to clearly show the coated regions. In Fig. 3 and 4, mouth regions 55 of outlet openings 32 lie in

the drawing plane. It should be emphasized that the coatings may also extend slightly into outlet 32.

In the exemplary embodiments shown, in each case valve seat element 26 is the component of fuel injector 5 that forms downstream end 8 and has outlet 32, so that the coating is to be applied at downstream end face 54 of valve seat element 26. However, the application of a coating according to the present invention is not limited to a valve seat element; instead, other valve components that form downstream valve end 5 and thus project into combustion chamber 3 may have such a coating as well. For such components (see spray-discharge member 67 in Figure 5) disposed downstream of valve seat 27, as well, at least the regions immediately at outlet openings 32 should be coated, so that the actual spray-discharge area is protected from coking.

Figure 5 shows an alternative guide and seat region at valve end 8 on the spray-discharge side, in order to illustrate that the assertions with respect to the coating of the present invention are also applicable to valve designs that differ structurally. In this exemplary embodiment, a further disk-shaped spray-discharge member 67 is disposed downstream of valve seat element 26. In this instance, spray-discharge member 67 has outlet 32. Outlet 32 is inclined at an angle with respect to the longitudinal valve axis, and terminates downstream in a convexly curved spray-discharge region 66. Spray-discharge member 67 and valve seat element 26 are permanently joined to one another by, for example, a welded seam 68 obtained by laser welding, the welding being carried out in an annular circumferential depression 69. In addition, spray-discharge member 67 is permanently joined to valve seat support 21 by a welded seam 61. For example, the coating is applied either over entire curved spray-discharge region 66, or directly in a ring shape about mouth region 55 of outlet

32, so that relative to the longitudinal valve axis, an off-center coating exists on a curved surface 54.

Figure 6 shows a longitudinal section through a fuel injector for auto-ignition internal combustion engines, particularly diesel engines, only the part facing the combustion chamber being shown. An enlargement of the end of fuel injector 5 on the combustion chamber side shown in Figure 6 is illustrated in Figure 7. A component constructed as valve member 72 is braced against a valve retaining member 73 with the aid of a tension nut 75. Formed in valve member 72 is a bore 84 in which piston-shaped valve needle 20 is disposed, which is axially movable against a closing force. Bore 84 is implemented as a blind-end bore, the closed end facing combustion chamber 3 forming a valve seat surface 27, which has an essentially truncated-cone-shaped form. Due to bulging of the end of valve seat surface 27 on the combustion chamber side, a blind hole 92 is formed in whose wall at least one outlet 90 is configured, which connects blind hole 92 to combustion chamber 3.

Valve needle 20 is divided into a section, facing away from combustion chamber 3, which has a larger diameter and is guided in bore 84, and a section having a smaller diameter, between which and the wall of bore 84, a pressure space 86 is formed, which is fillable with fuel under high-pressure via an inlet channel 80 formed in valve retaining member 73 and valve member 72. Due to the grading of the outside diameter of valve needle 20, a pressure shoulder 82 is formed on it, which is situated within pressure space 86. The fuel pressure in pressure space 86 produces a force on pressure shoulder 82 whose component operating in the axial direction is directed contrary to the closing force operating on valve needle 20, and thus, given suitable fuel pressure, valve needle 20 is able to move against the closing force.

Formed on valve needle 20 at the end on the combustion chamber side is a valve sealing surface 88, forming valve-closure section 28, which cooperates with valve seat surface 27 in such a way that the at least one outlet 90 is sealed against pressure space 86 by the contact of valve sealing surface 88 on valve seat surface 27. Due to the opening lift movement directed inwardly away from combustion chamber 3, valve sealing surface 88 lifts off of valve seat surface 27 and connects pressure space 86 to outlet 90.

The catalytically active coating is applied, for example, over the entire end face of valve member 72 facing combustion chamber 3. It is also possible to provide only curved outer surface 96 of blind hole wall 93, which borders blind hole 92 and in which the at least one outlet 90 is formed, with a coating. Provision can also be made to continue the coating into outlet 90.

What Is Claimed Is:

1. A fuel injector (5), particularly a fuel injector (5) projecting directly into a combustion chamber (3) of an internal combustion engine, having a fuel intake nipple (7), having a movable valve closure member (28), having a fixed valve seat (27) with which the valve closure member (28) cooperates for opening and closing the valve, and having a fuel outlet formed in a downstream valve end (8), the fuel outlet being formed by at least one outlet (32, 90) disposed downstream of the valve seat (27), wherein the component (26, 67, 72) having the at least one outlet (32, 90) has, at least in mouth region (55) of the outlet (32, 90), a coating around the outlet.

2. The fuel injector as recited in Claim 1, wherein the fuel injector projects into the combustion chamber (3) of an internal combustion engine having externally supplied ignition.

3. The fuel injector as recited in Claim 1, wherein the fuel injector projects into the combustion chamber (3) of a self-igniting internal combustion engine.

4. The fuel injector as recited in one of the preceding claims, wherein the coating is provided in a ring shape about the outlet (32, 90) of the downstream surface (54, 96) of the component (26, 67, 72).

5. The fuel injector as recited in one of the Claims 1 through 3, wherein the coating is provided over the entire surface on the downstream surface (54, 96) of the component (26, 67, 72).

6. The fuel injector as recited in one of the Claims 4 or 5, wherein, in addition to coating the surface (54, 96) of the component (26, 67, 72), the coating also extends into the outlet (32, 90).

7. The fuel injector as recited in one of the Claims 1 through 6,
wherein the coating is in the form of a catalytically active layer of Co or Ni, or cobalt or nickel oxides, or oxides of Co- or Ni-alloys, or Ru, or Rh, or Pd, or Os, or Ir or Pt, or alloys of these metals among themselves and/or with other metals.

8. The fuel injector as recited in Claim 7,
wherein the layer is able to be produced by electrochemical metal deposition or metal deposition without external current.

9. The fuel injector as recited in one of the Claims 1 through 6,
wherein the coating is implemented as metal-containing or metal-free carbon layer.

10. The fuel injector as recited in one of the Claims 1 through 6,
wherein the coating is implemented as fluorine-containing layer.

11. The fuel injector as recited in Claim 10,
wherein the fluorine-containing layer is a layer of fluorosilicate (FAS).

12. The fuel injector as recited in one of the Claims 1 through 6,
wherein the coating is implemented as nitride layer (TiN, CrN).

13. The fuel injector as recited in one of the Claims 1 through 6,
wherein the coating is implemented as tantalum oxide layer or titanium oxide layer.

14. The fuel injector as recited in one of the preceding claims,
wherein the component having the at least one outlet (32, 90) is a valve seat element (26, 72) also having the valve seat (27).

15. The fuel injector as recited in Claim 14,
wherein the valve seat element (26) has an upstream end face on which the valve seat surface (27) is formed, and it has a downstream end face (54), opposite the upstream end face, on which the coating is applied.

Abstract

The invention relates to a fuel injector (5), particularly a fuel injector projecting directly into a combustion chamber (3) of an internal combustion engine, having a fuel intake nipple (7), having an energizable actuating element (10, 11, 19) by which a valve closure member (28) is able to be moved, having a fixed valve seat (27) with which the valve closure member (28) cooperates for opening and closing the valve, and having a fuel outlet formed in a downstream valve end (8), the fuel outlet being formed by at least one outlet (32) disposed downstream of the valve seat (27). The valve seat element (26) having at least one outlet (32) has on its downstream end face (54), at least in mouth region (55) of the outlet (32), a coating which prevents coking in this region.